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The Indian solar photovoltaic industry: a life cycle analysis

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Abstract

This paper applies the product life cycle framework to analyze the impact of global trends on the Indian photovoltaic industry. The author believes that consolidation in the Indian industry simultaneous with exploiting its comparative advantage of flexible and low cost production techniques would help it stand on its own feet beyond the protectionist subsidy era. Service provision and financing are likely to represent significant revenue opportunities while dwindling margins on module manufacture would expedite formation of vertically integrated energy service delivery chains.

Keywords: Indian solar PV industry; Consolidation; Vertical integration

Contents

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1. Introduction

The renewable energy sector in general and Solar Photovoltaic (PV) technology in particular are often labeled the 'sunrise' industry and are said to be in their 'infancy', but, more recently, analysts and economists have charged it with being in this state for too long [5]. Solar PV's promised drastic cost reductions have not materialized [20] and potential market sizes have been grossly overestimated, according to Bradley [2]. One general observation is that the industry has been pampered with grants and subsidies and accorded special treatment the world over, and it is time to subject it to rigorous economic analysis alongside other 'normal' industries. Apart from the social and ecological aspects of growing the solar PV industry, a strategic approach needs to be adopted to identify the financial and economic barriers [26], causing the gap between the actual and the potential deployment as a starting point to designing innovative energy policies and to creating an enabling environment [36]. Polatidis and Haralambopoulos [23] have found that a longterm normative perspective for renewable energy decisions covering political, legislative, administrative, economic and marketing issues is an important prerequisite for their successful deployment. This article is an attempt to apply conventional theories of economics and business to the Indian Solar PV industry, predominantly the solar module manufacturing operations, and to chart a course for its evolution beyond the protectionist and subsidy era.

However, from governments' perspective, beyond export markets and technological leadership, the prospect of reduced imported oil dependence, air pollution, nuclear safety risks, and climate disruption provide additional justification for the deployment of micropower technologies such as SPV, globally [22]. In India, reducing the need for the extension of the utility power grid and limiting transmission and distribution losses and theft of power for the electricity boards and their successors could be additional drivers for government policy.

2. The product life cycle

Most industries evolve and go through a life cycle, typically mimicking the biological life cycle. Klepper and Graddy [13] have reported the regularity of the product life cycle (PLC) of 46 products. The industry comes into existence and begins to grow in stage I, often as a result of an innovation. During stage II, referred to as the shakeout phase, companies exit at an even faster rate than their entry and stage III refers to maturity of the industry, followed by its eventual decline and replacement. A general consensus exists among authors that once a product is launched, imitators appear rapidly and in great numbers, expanding output dramatically, resulting in falling prices [37]. The market then selects product designs and R&D tends to shift from an emphasis on improvements in product design to improvements in the production process itself. Firms with superior production and distribution and relatively greater improvements than the competition survive the shakeout. Once the industry matures, the industry concentration does not change dramatically, while R&D is concentrated on cost reducing innovations and minor improvements in product design. Some products suffer technological obsolescence and, in due course, die out [18].

The PLC approach has been applied to various settings, from the hitech commercial mainframe computer industry [4] to unsophisticated cowpea based agricultural products

[19]. Werker [38] observes that 'a crucial characteristic of the product life cycle approach is that markets change from being more favorable for entrants to being favorable to established firms'. Karlsson and Nystrom [10] have found evidence of differences in knowledge intensity for firms in different stages of the product life cycle. This article endeavors to apply the PLC framework to the solar PV industry and given the background of relevant global developments, project the next steps for the Indian industry, which would enable it to survive and grow.

Jovanovic and MacDonald [9] have attributed shakeouts to major technological innovations more or less exogenous to the industry. In the present context, we could consider large scale success with thin-film technology (favorable) or commercially successful alternatives, viz. fuel cells (unfavorable) leading to a shakeout. More relevant and immediate, however would be cost advantages and economies of scale [12] in enhancing efficiencies of the production process. It has been observed that the solar PV industry has settled on the end product (predominantly crystalline silicon) and cost differences dominate product differences. According to Jackson and Oliver [7], it is possible to 'envisage a virtuous circle of market growth, expanded production and further economies of scale' in the near term.

3. Background and industry global trends

The world-wide solar PV industry has seen dramatic growth rates of 27% over the past 5 years, even reaching 32% yoy in 2003, when 742 MWp[2] of cells were sold, taking the cumulative world production to 3145 MW [8]. The global solar industry has grown to $7-billion per annum, largely on the back of government incentive programs, together with lower prices secured through volume purchases. The industry has experienced an annual growth rate in excess of 18% in over the past decade [21]. This has resulted in the progressive reduction in cell/module prices as in Table 1[3] and Fig. 1[4] owing to scale economies, more efficient production techniques and to a lesser extent, to incremental cell/module efficiencies.

These benchmark prices [25] are based on annual purchase orders, or large projects requiring over 50 kW of modules. PV prices are projected to further reduce by 5% per year [15] to year 2010, or by 20% with experience gained with every doubling in installed capacity according to the European Renewable Energy Council [3,8].

The prices for PV modules prevailing in the international markets are determined by the dynamics of demand and supply, launch of subsidy programs in different countries and the production volumes and efficiencies of relatively large manufacturers. The general observation is that producers have been progressively ramping up production capacities to meet projected prices and no single producer might be in a position to exercise substantial market power, even in what, at first sight, appears to be an oligopolistic setting. This could be attributed to the nature of the industry and its current level of maturity, given that demand is largely driven by subsidy programs and other government and donor initiatives and procurement is generally managed or supervised by industry experts.

[2]MWp = mega Watt peak and kWp = kilo Watt peak.
[3]Photovoltaic Markets, Technology, Performance and Cost: 1975–2010—PV Energy Systems, Inc.
[4]http://www.eia.doe.gov/cneaf/solar.renewables/rea_issues/solar.html.

Table 1
Price decline in solar PV modules over the period 1992–2001

Module prices (US$, FOB factory, single and polycrystalline silicon)										
Year	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Price	4.25	4.25	4.00	3.75	4.00	4.15	4.00	3.50	3.75	3.50

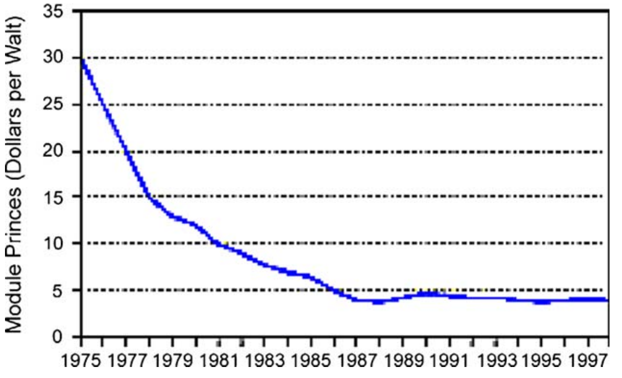


Fig. 1. Declining prices of solar PV over a two decades.

While the PV industry was regarded as being in the early part of the learning process during the last decade [20], clearly, we observe the signs of a maturing industry. More discerning is the evidence of the shake out and consolidation phase in the industry—the increase in market concentration and the squeezing out of relatively smaller players. In early 2002, Shell Renewables bought out a joint venture with Siemens and E.ON to become one of the larger PV companies in the world. This has been hailed as 'good news for customers, staff and partners, and for the whole solar industry', as the 'integrated company will have the people, the reach and the resources to build a sustainable, commercially successful solar PV business around the world' [29]. Denmark based Vestas and NEG Micon justified their merger 'citing size, technological know-how and development as well as financial strength as the major prerequisites for growth and long-term survival' in the highly competitive international renewables market [30].

The world PV market is supplied by a large number of players, though large production capacities are concentrated in the hands of the top 10 producers—336.34/390.5 MWp or 86% of total production in 2001, according to Maycock [17]. Japanese PV manufacturers were the leaders in 2002 with production of 251 MW, the United States at 100 MW, Germany 57 MW and Spain 44 MW out of total global production of 535 MWp. Other production centers included India 19.6 MW, France 17.5 MW, Australia 8.4 MW, Italy 7.5 MW and Britain 3 MW [11].

Some of the producers, especially from Japan have pulled ahead of the competition by growing volumes at rates substantially higher than the overall market. One such case is that of the current market leader, Sharp® with a global market share of 27% and whose growth has been about twice the rest of the market as shown in Fig. 2. In other instances, (Refer Table 2[5] for CAGR 1995–2002) players have matched capacity increases to market

[5]www.oja-services.nl/iea-pvps/conference/downloads/s51-hoffmann.pdf.

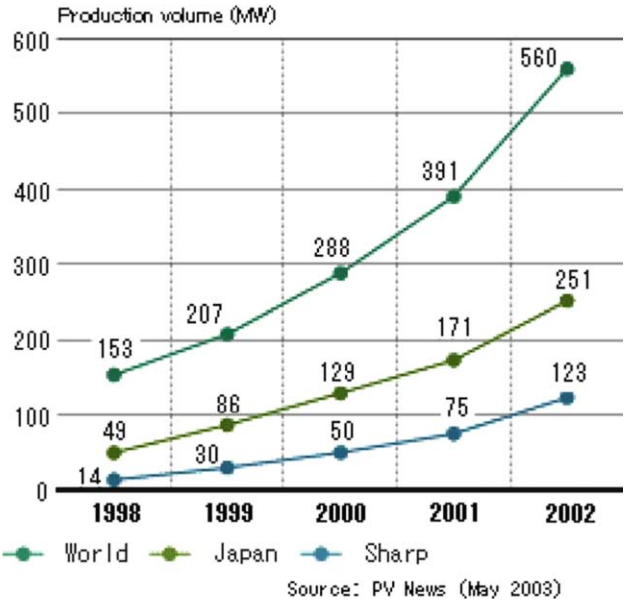


Fig. 2. The growth of sharp® production relative to rest of the market.

Table 2
Compounded annual growth rates of solar PV production over 1995–2002

MW	1995	1998	2001	2002	CAGR (1995–2002; %)
Sharp	3	8	75	123	70.0
Kyocera	6	20	54	60	38.9
BPSolar	16	27	54	70	23.5
Shell	16	19	39	48	17.0
RWE Schott Solar	4	6	23	29	32.7
Sanyo	4	4	19	35	36.3
World total	78	155	390	562	32.6

growth, while few of the players have announced ambitious expansion plans. Consequently, in calendar 2003, the five manufacturers of PV cells—Sharp, Kyocera, Shell Solar, BP Solar, and RWE Schott Solar accounted for 60% of the market output [8].

The market has also drawn the line between the technology and research intensive cell production and the rather labor intensive module-making operations. Some of the European plants now focus exclusively on cells (viz. Q.Cells, Germany) while modules get made in countries, where skilled labor is abundant and cheap.

Given this background of increasing concentration and declining prices, we are now in a position to investigate the impact of these global trends on the Indian industry. The author would like to study the consequences of the shake out and industry maturity on Indian units and identify their sources of comparative advantage.

Proposition 1. *Consolidation and shake-out in the Indian PV module industry is imminent and may be considered almost inevitable.*

The Indian solar photovoltaic module manufacturing industry comprises over 20 companies with aggregate production capacity of over 70 MWp [27,34]. This, however, includes the recently enhanced capacity of one of the firms, bestowing it with almost 55% of the industry capacity. The remaining part of the industry capacity is divided among several government, joint sector corporations and private companies. A large number of the fringe module manufacturers sell complete lanterns and PV systems and services rather than modules by themselves.

Global players have invested heavily in automated facilities and large capacities, while, in contrast, capacity addition by most Indian producers has been marginal and capacity utilization, low. There exists little or no difference in technology within the industry, as most Indian module manufacturing tends to be highly labor-intensive. In the Indian Solar PV industry, like most other industries worldwide, we can expect that with increasing scale, a firm's marginal cost is lower than its average cost of production. The Indian industry is bound to experience progressively rising real and nominal labor costs, and, in the face of declining product prices, margins could be sustained only if the Indian producers scale up rapidly to derive the benefits of scale and increase capacity utilization approaching global standards. Sub-optimal plants can exist for brief periods, by doing things differently [1], but are eventually likely to be overwhelmed by developments. By 2007, we could expect aggregate Indian industry production capacity to top 120 MWp[6] but substantially more concentrated, with an average production capacity far greater than the present mean of about 3 MWp. Some of the players would terminate cell manufacturing and restrict themselves to larger volume module operations using imported cells. With declining tariff barriers and as the industry looks at markets beyond the subsidy programs, the smaller players would have to migrate to service delivery or exit the industry completely. This is in also line with Hoffman's findings [6] that, renewable energy/energy efficiency businesses, upon deregulation, would ultimately consolidate into fewer and larger firms. While there are indications that the government owned module manufacturers are also planning to ramp up capacities, their marketing strategies are not entirely clear.

Presently, production at some plants occurs in spurts, following launch of subsidy programs in India or overseas, while average capacity utilization over time remains low. Organized marketing efforts from larger producers and powerful brands would be required to enhance and even-out production. The larger players are likely, also, to be better placed to enhance capacity utilization, by promoting their brands more aggressively and by attracting professional management talent, requisite investments and timely working capital.

Proposition 2. *Vertical integration with service providers necessary to compete in the domestic consumer markets.*

Renewable Energy Service companies and PV systems are not expected to be substitutes for the electricity grid. These mini-utilities help reduce peak loads, reduce transmission and distribution losses and help optimize grid extension and usage and we could expect them to play a more formal role in the near future [16]. PV brings the service closer to the ultimate

[6]Assuming an annual increase in capacity of about 20% in line with global capacity expansion.

consumer, as Seetha [28] puts it, water for the farmer, light for the family and better indoor air quality for the entire household. Improved competition among these solar utilities ultimately benefits the customer. The business risk for the service companies, themselves, is reduced by the smaller capital outlays required and the shorter gestation periods.

Solar home systems (SHS) have by far represented the rural electrification market using PV systems.[7] Certain parts of the country have witnessed steady volume growth on the back of government sponsored capital subsidy programs, and others have made extensive use of third party credit from commercial banks, rural cooperatives, etc. Invariably these markets are served by system integrators and service providers such as SELCO India, Shell Solar India (both based in Bangalore), TATA BP dealerships, Environ Energy Tech Systems (Calcutta) and NGOs and social organizations such as the Ramakrishna Mission (RKM) and the Social Work Research Center (SWRC). These integrators are typically, local or regional players and benefit from an in-depth knowledge of the socio-economic-political realities in their geographies and enjoy a good rapport with their customer base and with financial intermediaries.

The urban power pack market would be opened to the PV industry as soon as banking with the utility grid and net-metering are permitted, as the operational economics are already rendered comparable to the ubiquitous Diesel generator [14]. The revenues accruing from the sale of the ecological benefits from these systems would expedite convergence with the grid or other possible alternatives, such as inverter based uninterruptible power supply systems (UPS).

Each PV service provider typically sources entire systems or components of systems from established manufacturers. These service providers, essentially, represent the domestic distribution arms of the module and component manufacturers, and are nimble enough to provide the grass-roots level customer interface and periodic service. As the market has grown and matured, most module (and other component) manufacturers realize that it is neither their core competence nor are they appropriately placed to provide these ‘energy services’ to the end customers, themselves. On the other hand, some of these dedicated service providers or energy service companies have achieved sufficient critical mass of installations, reputation for service and the momentum required to expand rapidly.

Solar energy service companies in some parts of the country represent substantial sales volumes—as much as a quarter of a MWp per year in some instances, thus enhancing their bargaining power with module vendors. Some of the service providers produce modules in small numbers and operate within limited geographies, while some of the module manufacturers provide service in selected locations, but this is definitely on the wane. A very encouraging observation is that customers are favorably disposed to paying a premium for better post-installation service, which some of the service providers have successfully exploited. Presently, a sizable portion of the revenues for the established players emanates from the maintenance contracts they execute with existing customers. These service providers are positioning themselves as environmentally responsible utilities and are expanding their PV portfolios horizontally to build regional scope.

While the domestic market provides a hedge against the volatility in export demand for modules, we observe two simultaneous trends developing. The bargaining power of the solar energy service companies is on the increase. A shift in procurement from one module

[7] For an extensive discussion on the segments of the Indian PV market, please refer to Srinivasan [32].

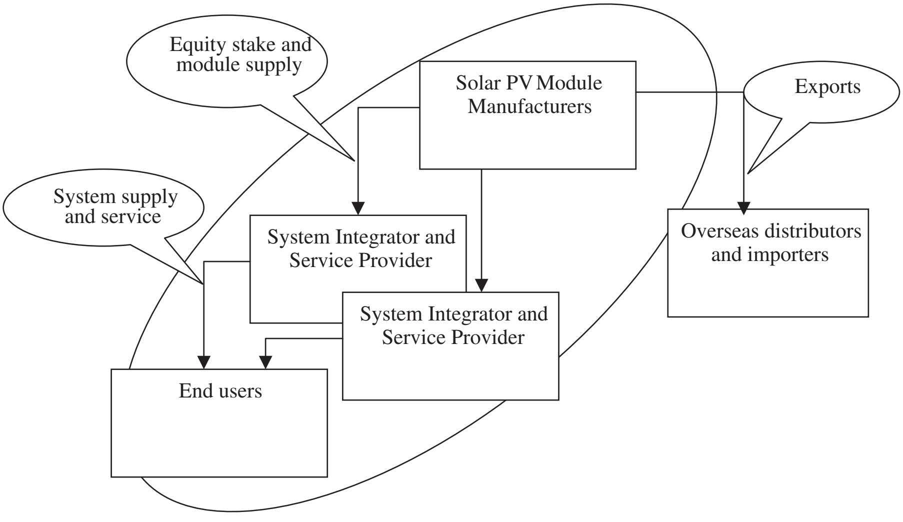


Fig. 3. The energy supply value chain.

manufacturer to the other, especially among the smaller manufacturers could have farreaching consequences—in the worst case, resulting in the bankruptcy of the former vendor. Simultaneously, international module prices are expected to fall at about 5% each year, thereby progressively squeezing manufacturing margins and almost eliminating the scope of price reductions or prolonged supplier credit. As the Worldwatch Institute puts it, 'New business models would have to evolve around the micro-power technologies' [22] and module manufacturers would attempt to lock-in the service providers.

In the next phase of consolidation and reorganization, and with further maturing of the industry, energy service provision and consumer financing would represent the predominant revenue opportunities and manufacturing of modules and components would drift to the background, with negligible profit margins. To keep the system integrators locked in, to ensure module offtake and to benefit from the service revenues, the module manufacturers would be encouraged to take equity positions in the energy service companies. Each manufacturer is likely, therefore be a minority equity holder[8] in a few energy service companies operating in different geographies. This equity infusion also strengthens the balance sheet of the service providers and provides them with much-needed liquidity, while assuring them of uninterrupted module supplies. The consequent structure of the reorganized energy service delivery value chain is shown in Fig. 3, and the author expects to witness the development of this structure commencing forthwith and culminating by about the end of the decade, in tandem with collapsing tariff barriers on imports.

The solar PV industry has been relatively insulated from competitive pressures and such reorganization would help it sustain itself and grow in the post-subsidy era. This is similar to the developments witnessed in other industries, where declining global product prices and reduced margins have necessitated a consolidation and an increased focus on service provision. The equity alliance between TATA Coffee and the Barista retail chain was

[8]Sufficient to ensure module offtake without management responsibility.

intended to result in backward and forward integration of the entire coffee value chain, allowing the partners to take ownership of the coffee category from 'bean to cup', even as international coffee prices remained depressed [35]. It is now a well known story that the financing arm of the automaker, General Motors has recorded increasing profits despite pricing pressures and production cuts in the mainstream manufacturing business [24].

Proposition 3. *Comparative advantage for Indian manufacturers would reside in the export of small modules for export*, (<70 *Wp*), *and the Indian market would benefit with the import of larger modules* (>70 *Wp*).

Over the last 5 years, an Indian business group attempted to import thin-film modules, which are, in theory, cheaper than crystalline modules, but found that the transportation costs and customs tariffs thereon rendered them price-uncompetitive within India. During the same period, a European firm attempting to export solar lanterns in a knocked down condition to India, for subsequent assembly and retail sales, faced similar cost barriers. The situation is set to change rapidly with simultaneous decline in international product costs and tariffs imposed thereon.

As discussed above, international module prices are slated to decline by about 5% each year, and when this price 'p^*' falls below the average cost of the Indian manufacturers, progressively, the smaller players in the industry cannot exist without tariff protection. We would soon encounter the situation, where the landed cost of imported modules (p^*+ customs tariff + Transportation cost) would be lower than the average cost of production at a small facility in India ($\cong 1.3$ times p^*, where customs tariffs and transportation costs are estimated at 30%), owing to the higher production efficiencies and scale economies accruing to large automated facilities abroad. At this stage, we are likely to see imported modules entering the Indian market and the consolidation of module making operations starting from the smallest units, upwards.

Exports are an integral part of the industry's growth and India is increasingly seen as a low cost manufacturing base for high-quality small modules (<70 Wp). Since most module manufacturing operations tend to be labor intensive, Indian producers are considered to be highly flexible compared to the automated plants in Japan, Europe and other parts of the world. Consequently, energy paybacks for modules from such plants are also far superior. Some manufacturers have tied up with large multi-nationals to manufacture on contract, with solar cells and a few other ingredients usually supplied by the principal. The government has supported export growth through various measures including duty exemptions on imported material (intended for re-export), subsidized interest rates on working capital facilities, etc. The Indian manufacturers have successfully exported to the highly competitive European grid-connected/roof top market and African rural electrification markets and are looking forward to expanding into Australia and South-East Asian nations.

By virtue of producing 'small' modules of varying sizes through flexible production techniques, often supported by international quality certification, the Indian exporters have managed to negotiate marginal premiums over international prices. Export related subsidies have therefore helped create a niche market for Indian manufacturers, a niche which is expected to grow as these export markets evolve. The industry views the export market favorably because it increases capacity utilization, brings in foreign exchange which could be used to pay for silicon wafer/cells and other imports, and because of its importance as a hedge against sluggish demand growth in the domestic market.

Proposition 4. *Imported solar modules would increasingly find their way into the rapidly growing commercial markets.*

Corporate houses in India have rolled out networks of internet kiosks in rural and semiurban areas to enhance information flow with these areas, help enhance farm productivity, improve farm-gate price realization and cut transaction costs. Agriculturists are now in a position to access latest and relevant information on weather, better farming practices as well as market prices, through specially designed internet portals—all in their respective vernacular languages. These kiosks also facilitate supply of farm inputs as well as purchase of the farm produce Soya Choupal [31]. Kiosk networks are also operated by provincial governments to provide e-governance services. Since most of these kiosks are located in areas with indifferent power supply, PV systems are the obvious source of power to operate these kiosks. Private telecom companies rolling out WLL[9] and other rural telecom services and have been ramping up their consumption of PV modules for powering network interface units, base, booster and repeater stations. Each of these market segments is on the verge of an explosion, given the emphasis placed on the use of ICT[10] to bridge the urban-rural divide.

Similarly, the market for cathodic protection, signaling, etc. is expected to grow exponentially as networks of oil and gas pipelines, highways, etc. are being developed by private players. Voice and data communication, signaling systems, cathodic protection and other miscellaneous applications thus, represent an obvious and large nation-wide market for PV systems.

Most of these PV systems are designed for the specific application in question and are essentially packaged with the appliances being powered. Service arrangements for these systems tend to be clubbed with the maintenance support for the rest of the hardware—the computers, printers, telecom equipment and other end use appliances.

The business model for commercial applications of PV modules would therefore represent design and delivery while maintenance could, typically, be carried out by third parties. This market could be viewed as being competitive insomuch that price, quality, reliability, brand equity and risk of delivery default would play a role in the procurement decision. Intra-industry differences in prices could be substantial, depending on the nature of the service arrangement sought by the client and the geo-spread of the installations.

With the elimination of capital subsidies on the solar lantern, it has literally become a consumer good. Solar lanterns are now positioned at various price points, with a range of features, specifications and aesthetic designs. While a few of the manufacturers supplying to the erstwhile subsidy market have exited the market, several entrepreneurs have since entered, making it a highly competitive segment of the solar PV commercial market. Innovative marketing strategies, financing options and service networks are being designed for this high-volume, low-margin product. Under the subsidy regime, a few of the lantern vendors also fabricated their own solar modules. The segment has witnessed a consolidation of sorts and recently, mutually beneficial arrangements have been made to source modules for the solar lantern from mainstream module manufacturers.

[9]Wireless in local loop.

[10]Information and communication technology.

Solar gadgets, viz. torch lights, toys, etc. are developed and manufactured in small quantities in the domestic market. Major supplies at competitive prices originate in China or elsewhere, but by the time they reach the Indian consumer, the price differential almost vanishes. It is less interesting from the module manufacturers' perspective as the typical PV consumption is very small and requires continuous product development and entirely different marketing strategies and channels.

Commercial markets are expected to see explosive growth. Product service could be provided by third parties, with or without previous experience in the industry. Systems are likely to be sold as an integrated kit along with the application in question—internet kiosks, signaling equipment, etc. The imported modules, especially >70 Wp, are likely to become much more affordable with production costs at large overseas facilities falling relative to Indian costs, simultaneous with falling customs barriers. This market segment would be willing to pay a premium for superior technical design and aesthetics and is therefore likely to be the first to witness the entry of imported modules, essentially packaged with the end-use application, viz. automated teller machines (ATM).

The solar lantern market has already matured to stand on its own feet while the consumer gadget market would be swamped by imported models and the Indian manufacturers are already on their way out of this segment.

Proposition 5. *Government (supported) programs would continue to absorb sizable output volumes but would need to encourage energy service companies to bid directly.*

The aggregate module production capacity in the country as of 2003 is in the order of 70 MWp, [27] and current production levels represent a capacity utilization of about 30%. Almost 55% of this capacity (38 MWp) is owned by one player, while the remaining industry is fragmented and in the hands of some 20 odd small and medium module manufacturers, with capacities ranging from under 1 to about 6 MWp.

The Indian industry represented 3.66% of the global module production in 2002. Out of 23 MWp produced in the country, by year-ended March 2003, 8 MWp were consumed in the country—and 15 MWp exported during the first year of the Tenth Five Year Plan

Table 3
Where the Indian solar module goes

Segment	Module consumption (MWp)
Exports	48
Subtotal (exports)	48.00
Lanterns	4.9
Solar home systems (SHS)	9.2
Subtotal (consumer)	14.10
Telecom	16.3
Others (signals, cathodic protection, etc.)	16.8
Subtotal (commercial)	33.10
Street light	3.5
Pumping	7.5
Power plants	3.8
Subtotal (government)	14.80
Grand total	110

(2002–2007) [33]. The cumulative consumption of solar modules produced in the country until May 2003 is as shown in Table 3 ([27] and MNES[11] Annual Report, 2003).

The target for domestic consumption of PV modules for the remaining four years of the current five year plan (2002–2007) period is 192 MWp (200 MWp less 2002–2003 deployment) of which, the Ministry hopes to support about 30% ([27], Planning Commission). We could presume with fair certainty that a large proportion of the Ministry supported consumption of PV would go into off-grid power plants, pumping systems, and street lighting while a small part of it would enter the subsidized stand-alone domestic lighting segment.

The Government procurement segment, largely works on a tender-quota process in one or another form. The power plant jobs are awarded on case-to-case, basing on certain technical qualification criteria and to the least cost bidder among qualifying participants and entail a commitment for post-installation service. Prices of agricultural pumping systems at which vendors execute supply orders, on the other hand, are almost fixed by the ministry, at the least bid price. Vendors receive certain quotas based largely on their ability to source, integrate, install and service the systems, subject to time and working capital constraints. On execution of the contract, they collect the subsidy amounts from the nodal agencies and the minor contribution from the farmer-owners of the pumping systems. Street lighting systems are intended to be 'owned' by the local government, *panchayats* and the like, and the procurement system works pretty much along the lines of the pumping systems, except that the entire capital cost is borne by the Ministry/government.

Power plants could vary in size from a few kWp to over 100 kWp and thus represent a very attractive opportunity to place sizable volumes of modules on the market in one go. And yet, these plants are often installed in remote areas, islands and mountainous regions, and consequently, it is quite challenging for the module manufacturers to provide postinstallation service. Additionally, the vendors are required to invest substantial amounts of working capital during the construction phase and subsequently, till such time payments from the Ministry/nodal agencies are realized. The most common way around the qualification criteria, the service-provision mandate and the working capital requirements is to partner with integrators/service providers who actually install and service the plant while the module manufacturers simply lend their names, supply modules and get paid upfront. Service provision in case of pumping systems is slightly more intensive and is of the highest intensity for the street lighting systems as the system sizes decrease and spatial dispersion is vastly increased.

This allocation of responsibilities and longer-term partnerships would be facilitated by the vertical integration discussed above. The procurement agency, therefore, has to recognize the trends in the industry and alter its qualification criteria to make room for system integrators to participate directly in the tendering process. It is also in the interest of the government to invite the largest of the producers to bid, and is often tempted to execute contracts at the prices bid by the larger firms but with several vendors so as to diversify risk of non-delivery. This approach is clearly unsustainable, as the smaller firms would not be in a position to match the costing of the larger firms and would hence compromise either on the quality of the components supplied or more commonly on the post-installation service.

[11]Federal ministry of non-conventional energy sources.

4. Summing up

The three segments of the Indian PV module market, namely the government, commercial and consumer segments are likely to grow in different proportions. Government procurement would remain steady and be dictated more by political convenience, rather than with industry evolution in mind. To encourage competition among domestic producers, the option of using imported modules should not be foreclosed. The qualification criteria need modification to permit the participation of professional system integrators and service providers directly in the tender process.

The most interesting developments are likely to be witnessed in the consumer segment. Integrated service delivery chains would be set up from the cell to the light in the consumer's household through partnerships between the professionally managed solar utilities and the module manufacturers. Since margins from the sale of modules alone would dwindle and service provision would represent increasing revenue opportunities, equity tie ups between module vendors and the service providers are imminent. Smaller module makers with existing service operations would tend to swap their production activities for enhanced service opportunities. The industry would therefore comprise a few module manufacturers, generally utilizing imported cells, each with equity positions in several miniutilities/service providers. The market is likely to grow on the back of commercial finance from rural and cooperative banks rather than on subsidy programs, and on the promise and evidence of disciplined post-installation service.

Consequently, financing and market development programs in India and other similar settings should be targeted at facilitating this consolidation in manufacturing operations and enhancing quality standards for the service operations and most importantly for attracting more banks and financial institutions into working capital and end-user financing for solar PV. Government policy should be directed towards making the industry competitive [39] in the international arena, and eliminating the perpetual need for financial assistance or concessions of any sort. Subjecting the photovoltaic industry to rigorous economic analysis alongside mainstream industry marks a turning point and provides policy makers with an opportunity to look at it differently, and restrict subsidies and preferred treatment to genuinely less-developed areas and under-privileged populations.

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